

ANCHORING THE DISTANCE SCALE VIA X-RAY/IR DATA FOR CEPHEID CLUSTERS: SU CAS

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ABSTRACT

New X-ray (XMM-Newton) and JHK_s (OMM) observations for members of the star cluster Alessi 95, which Turner et al. (2012) discovered hosts the classical Cepheid SU Cas, were used in tandem with UCAC3 (proper motion) and 2MASS observations to determine precise cluster parameters: $E(J - H) = 0.08 \pm 0.02$ and $d = 405 \pm 15$ pc. The ensuing consensus among cluster, pulsation, IUE, and trigonometric distances ($d = 414 \pm 5(\sigma_{\bar{x}}) \pm 10(\sigma)$ pc) places SU Cas in a select group of nearby fundamental Cepheid calibrators (δ Cep, ζ Gem). High-resolution X-ray observations may be employed to expand that sample as the data proved pertinent for identifying numerous stars associated with SU Cas. Acquiring X-ray observations of additional fields may foster efforts to refine Cepheid calibrations used to constrain H_0 .

Subject headings: Hertzsprung-Russell and C-M diagrams—infrared: stars—open clusters and associations—stars: variables: Cepheids—X-rays: stars.

1. INTRODUCTION

Turner et al. (2012) discovered that the 1.95^d classical Cepheid SU Cas is a member of the star cluster Alessi 95. The discovery permitted the fundamental parameters ($\log \tau$, $\mathcal{M}_*/\mathcal{M}_\odot$, E_{B-V} , M_V , R_*/R_\odot) for SU Cas to be inferred from cluster membership, thereby enabling a long-standing debate concerning the Cepheid's distance and pulsation mode to be resolved (Gieren 1976, 1982; Evans 1991; Usenko et al. 2001; Turner et al. 2012, and references therein). Previous uncertainties associated with SU Cas permeated into efforts to anchor the short-period regime of the Cepheid period-luminosity relation. SU Cas is the vital link since the variable is among the shortest-period Galactic Cepheids known (Berdnikov 2008), and the nearest such star (Berdnikov et al. 2000)¹. The Cepheid's proximity allows for independent confirmation of its distance via trigonometric parallax (Hipparcos, Perryman & ESA 1997; van Leeuwen 2007; Turner et al. 2012). A principal research objective is to establish Cepheid calibrators with distances secured by independent means: e.g., infrared

surface brightness technique (ISB, Fouque & Gieren 1997; Gieren et al. 2005; Barnes 2009; Storm et al. 2011), cluster membership (Turner 2010; Majaess et al. 2011b), IUE-binary (Evans 1992, 1995), and trigonometric parallaxes (van Leeuwen 2007; Benedict et al. 2007). Achievement of that goal will facilitate efforts by the Carnegie Hubble (Freedman & Madore 2010) and SH_0ES (Macri & Riess 2009) projects to determine H_0 reliably, and break degeneracies complicating the selection of a cosmological model (Riess et al. 2011). Incidentally, the prototype of the class (δ Cep) has the most precise Cepheid distance established ($d = 272 \pm 3(\sigma_{\bar{x}}) \pm 5(\sigma)$ pc), which is tied to a cluster distance from $UBVJHK_s$ photometry (Majaess et al. 2012a), Hipparcos trigonometric parallaxes for cluster stars (de Zeeuw et al. 1999; van Leeuwen 2007; Majaess et al. 2012a), an ISB distance (Gieren et al. 2005; Storm et al. 2011), and Hipparcos/HST trigonometric parallaxes for the Cepheid and its companion HD213307² (Benedict et al. 2002; van Leeuwen 2007). ζ Gem is another nearby Cepheid which exhibits a precise mean distance ($d = 363 \pm 9(\sigma_{\bar{x}}) \pm 26(\sigma)$ pc, Majaess et al. 2012b) tabulated from cluster member-

¹Polaris is nearer (Turner 2009; Turner et al. 2012), yet exhibits a pulsation period $\sim 2\times$ larger than SU Cas (Berdnikov 2008). However, that does not mitigate Polaris' importance for the distance scale.

²XMM-Newton data confirm that HD213307 features a companion (Benedict et al. 2002). δ Cep is thus a multiple system, somewhat analogous to Polaris (Evans et al. 2010).

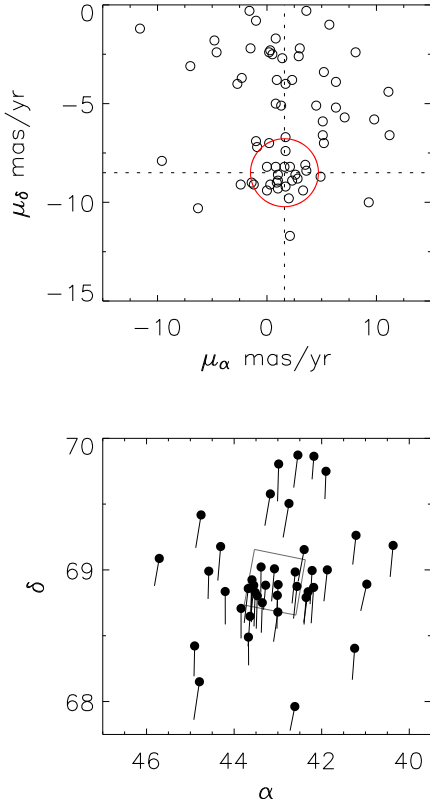


Fig. 1.— Top panel, UCAC3 proper motions for brighter stars within $r \sim 35'$ of SU Cas. Cluster members aggregate near the proper motion estimate for SU Cas ($\mu_\alpha = 1.0 \pm 0.7$ and $\mu_\delta = -8.6 \pm 0.8$ mas/yr). Field contamination becomes more acute with increasing distance from the cluster center, thus the sample was restricted to $r \leq 35'$ to highlight the cluster's significance. Bottom panel, the cluster core is discernible in the spatial distribution of stars $r \leq 60'$ from SU Cas which exhibit $\mu_\alpha = -0.5 \rightarrow 5.0$ and $\mu_\delta = -6.0 \rightarrow -10.5$ mas/yr ($\sigma < 5$ mas/yr). Proper motion trajectories (10^5 yr) are overplotted merely for illustrative purposes. The area bounded by the solid lines represents the approximate region sampled by XMM-Newton.

ship and HST/Hipparcos parallaxes. The desire to incorporate SU Cas into that select sample of fundamental Cepheid calibrators is the impetus for this research (see also Turner et al. 2012).

In this study, new X-ray and JHK_s data from XMM-Newton (Jansen et al. 2001) and l'Observatoire Mont-Mégantique (OMM, Artigau et al. 2010) are presented for Alessi 95. X-ray observations provide a means of segregating cluster members from field stars (Randich et al. 1996; Evans 2011), while OMM data supply more reliable photometry for fainter stars than 2MASS.

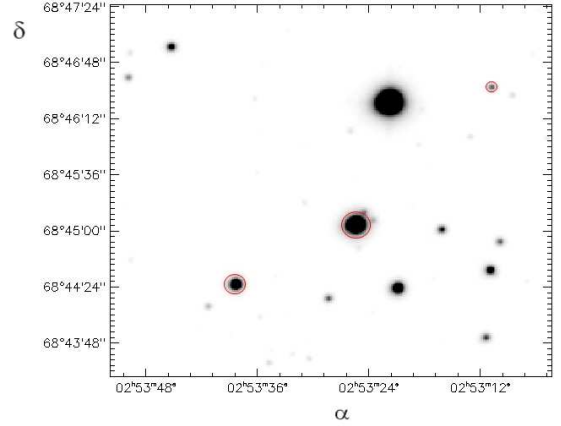


Fig. 2.— Finder chart (OMM J) for three probable cluster members which are X-ray sources. The two brighter objects exhibit UCAC3 proper motions (e.g., $\mu_\alpha = 0.8 \pm 1.0$ and $\mu_\delta = -8.2 \pm 0.8$ mas/yr) matching that established for SU Cas ($\mu_\alpha = 1.0 \pm 0.7$ and $\mu_\delta = -8.6 \pm 0.8$ mas/yr). The stars are probable cluster members based on X-ray, proper motion, and color-magnitude data (Fig. 3). The finder chart represents a small portion of the observed field.

2. ANALYSIS

2.1. BRIGHT CLUSTER MEMBERS

The positions for stars $r < 35'$ from SU Cas that feature UCAC3 (Third U.S. Naval Observatory CCD Astrograph Catalog, Zacharias et al. 2010) proper motions and 2MASS photometry are shown in Fig. 1 (top panel). The stellar overdensity near the proper motion for SU Cas ($\mu_\alpha = 1.0 \pm 0.7$ and $\mu_\delta = -8.6 \pm 0.8$ mas/yr) represents the cluster Alessi 95. The analysis was subsequently expanded and forty-five stars with similar proper motions to SU Cas ($\mu_\alpha = -0.5 \rightarrow 5.0$ and $\mu_\delta = -6.0 \rightarrow -10.5$ mas/yr, $\sigma < 5$ mas/yr) were detected within $\sim 1^\circ$ of the Cepheid. The positions and proper motions of those objects are displayed in Fig. 1 (bottom panel), and the cluster core is discernible in that diagram. Twenty-seven of the proper motion selected stars within $r \lesssim 40'$ of SU Cas (Fig. 1) form a distinct main-sequence in the JH color-magnitude diagram (Fig. 3). Only one star from the proper motion selected sample (Fig. 1) exhibiting $r \lesssim 40'$ appears to be a non-member, reaffirming that the proper motion data efficiently separate cluster members from field stars (Figs. 1, 3). An inability to distinguish cluster members from field stars hinders isochrone fitting, and exacerbates uncertainties tied to the derived distance. For example, the host cluster for ζ Gem proved more difficult to assess owing to the small offset of its proper motion relative to the field, particularly given the uncertainties (Majaess et al. 2012b). That shortcoming may be addressed by acquiring XMM-Newton/Chandra observations to identify cluster members, as later-type stars associated with ζ Gem ($\log \tau = 7.85 \pm 0.15$, Majaess et al.

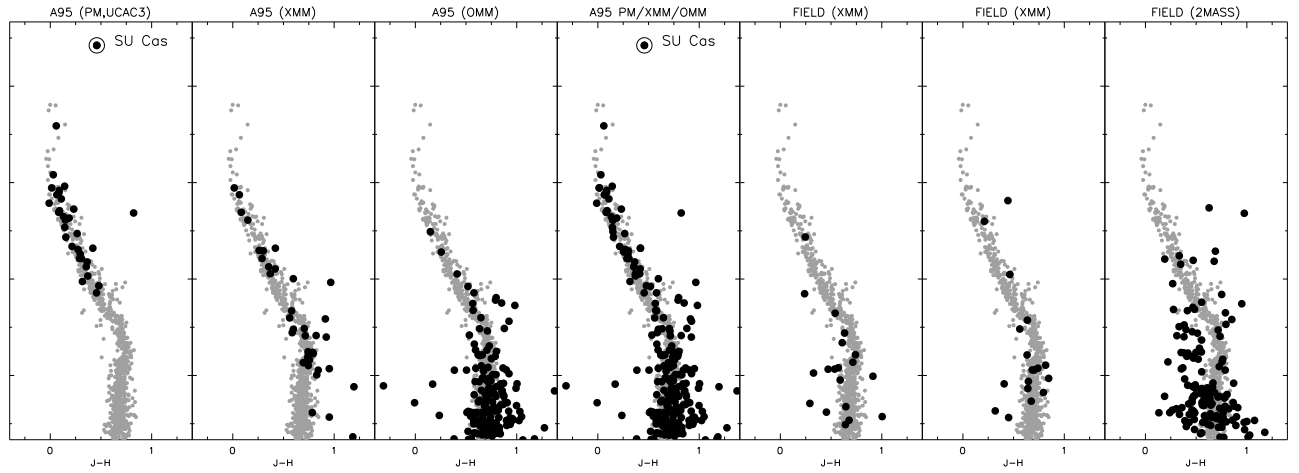


Fig. 3.— JH color-magnitude diagrams for stars exhibiting similar proper motions to SU Cas (PM, UCAC3), stars emitting X-rays (XMM), and OMM stars sampled $r < 4'$ from the center of Alessi 95 (A95). Gray dots are calibration stars from Majaess et al. (2011a). Comparison fields sampled by XMM-Newton and 2MASS imply that the cluster (A95) distribution is not fortuitous.

2012a) may emit X-rays owing to their comparative youth (Randich et al. 1996; Evans et al. 2010; Evans 2011). Independent confirmation of the ζ Gem cluster (Majaess et al. 2012a) is desirable.

X-ray data for the SU Cas field (PI Guinan) were obtained from the XMM-Newton public data archive (XSA). Point sources identified via the XMM-Newton (PPS) Processing Pipeline Subsystem (Fig. 2) were correlated with 2MASS photometry (closest source within $0.1'$). The majority of the X-ray sources lie directly on the cluster main-sequence (Fig. 3), and the field stars are readily discernible in the diagram (e.g., objects redder than M-type cluster dwarfs). X-ray observations are a pertinent means for identifying cluster members in harmony with other methods. The brightest star in Fig. 2 (BD+68°201, B9III-IV, Turner et al. 2012) may exhibit a later-type companion which is the source of the X-ray emission, since later-type B stars are typically X-ray quiet (Evans 2011, and references therein). BD+68°201 and SU Cas exhibit analogous UCAC3 proper motions, to within the uncertainties. The faintest star in Fig. 2 is likely an M-type cluster dwarf, as implied by its JHK_s photometry. A list of the X-ray sources and their corresponding 2MASS data are available via the XMM-Newton public data archive (PPS products).

2.1.1. MEAN REDDENING FOR ALESSI 95

A JHK_s color-color analysis of the UCAC3/XMM sample was performed to determine the mean reddening. The JHK_s intrinsic relations of Straizys & Lazauskaitė (2009) and Turner (2011) were employed to infer a mean color excess of $E(J - H) = 0.08 \pm 0.02$. That result is tied to a reddening law of $E(J - H)/E(H - K_s) = 2.0$ (Straizys & Lazauskaitė 2009; Majaess et al. 2011b). Stars which lie above the main-sequence (potential binary systems) in the color-magnitude diagram were ex-

cluded from the determination, in tandem with other stars exhibiting anomalous JHK_s colors. The mean color excess determined agrees with the optical excess established by Laney & Caldwell (2007), Kovtyukh et al. (2008), and Turner et al. (2012) (see also Table 5 in Evans 1991, and references therein). The conversion from the infrared to optical reddening is somewhat uncertain (Bonatto et al. 2004; Majaess et al. 2008, and references therein). Therefore, the optical reddening ($E_{B-V} \sim 0.30 \pm 0.05$) derived from $E(J - H)$ exhibits larger uncertainty to reflect that ambiguity.

2.2. FAINTER CLUSTER MEMBERS

Deeper JHK_s images were obtained for the SU Cas field from the OMM. The OMM houses a 1.6-m telescope equipped with a near-infrared wide-field imager (CPAPIR³). The images were acquired on January 11, 2012. PSF photometry was performed using DAOPHOT (Stetson 1987). The instrumental photometry was subsequently tied to 2MASS secondary standards in the field. A color-magnitude diagram was tabulated for stars within $r < 4'$ of the cluster center to mitigate field contamination. OMM JHK_s photometry for stars near the core of Alessi 95 shall be tabulated online at CDS or WEBDA (Pauzen 2008).

Comparison fields displayed in Fig. 3 reaffirm the existence of Alessi 95. However, the analysis is complicated by the cluster's extent, high latitude position ($\ell, b \sim 133, 9^\circ$) and inhomogeneous reddening. The first XMM-Newton comparison field lies beyond the coronal radius (02:05:55 +64:56:33, $r \sim 6^\circ$), however, hierarchical clustering observed in giant molecular clouds implies that members may still be sampled. The second XMM-Newton comparison field encompasses another classical Cepheid (β Dor). The 2MASS comparison field (Fig. 3,

³<http://www.astro.umontreal.ca/cpafir>

far right panel) is equal in area to the $r \sim 4'$ OMM sampling, but traces a symmetric annulus $r \sim 5^\circ$ away. Field contamination will be most acute for the fainter OMM data.

No low-mass stars are visible in HST WFC3 images for SU Cas (HST Proposal 12215, Evans 2009). The saturation from the Cepheid was treated by subtracting (normalized) the image from a master, which was constructed (median combine) using numerous Cepheids observed for proposal 12215 (see also Evans 2011). The late B-type (B9.5V) companion discovered by Evans (1991, her Fig. 4) via IUE observations was not detected, indicating that the star is in rather close proximity to the Cepheid. A comprehensive analysis is forthcoming (Evans et al., in prep.).

2.3. DISTANCE TO ALESSI 95

A precise distance may be established for the cluster via main-sequence fitting. The infrared (2MASS/NOMAD) calibration presented by Majaess et al. (2011a) was employed since it offers numerous advantages. First, the JHK_s calibration is comparatively insensitive to variations in $[\text{Fe}/\text{H}]$ and age (Majaess et al. 2011a, see also Straizys & Lazauskaitė 2009). Second, the deep JHK_s photometry extends into the low mass regime ($\simeq 0.4M_\odot$) where $J - K_s$ remains constant with increasing magnitude ($M_J \gtrsim 6$) for low mass M-type dwarfs, and $J - H$ exhibits an inversion (see Fig. 3, Majaess et al. 2011a, and references therein). The trends ensure precise JHK_s main-sequence fits by providing distinct anchor points in color-magnitude and color-color diagrams (Fig. 3). Third, the calibration's zero-point is tied to seven benchmark open clusters ($d < 250$ pc) which exhibit matching JHK_s and revised Hipparcos distances (the Hyades, α Per, Praesepe, Coma Ber, IC 2391, IC 2609, and NGC 2451, van Leeuwen 2009; Majaess et al. 2011a, see also McArthur et al. 2011). The scale is anchored using clusters where consensus exists, rather than the discrepant case (i.e. the Pleiades). The objective is to avoid deriving distances to Cepheid clusters using a single benchmark cluster, and prevent the propagation of ambiguity into the Cepheid calibration. The revised Hipparcos distance for the Pleiades is $d = 120.2 \pm 1.9$ pc (van Leeuwen 2009), whereas JHK_s data implied $d = 138 \pm 6$ pc (Majaess et al. 2011a), and Soderblom et al. (2005) employed HST to deduce $d = 134.6 \pm 3.1$ pc. By contrast, van Leeuwen (2009) obtained $d = 172.4 \pm 2.7$ pc for α Per, which matches that established via the JHK_s analysis (Majaess et al. 2011a, their Table 1). Fourth, potential variations in the JHK_s reddening and extinction laws are predicted to be comparatively smaller than in the optical. Obscuration by dust is less significant in the infrared ($E_{J-H} \sim 0.3 \times E_{B-V}$, Majaess et al. 2008; Bonatto et al. 2004, and references therein), which consequently mitigates the impact of variations in R_λ ($J_0 = J - E_{J-H} \times R_J$). The ratio of total to selective extinction R_J was adopted from Majaess et al. (2011b)

(see also Bonatto et al. 2004). The offset from the calibration yields a distance to Alessi 95 of $d = 405 \pm 15$ pc.

2.4. DISTANCE TO SU CAS

A mean distance to SU Cas may be derived from the new JHK_s cluster parameters established here (the Cepheid lies near cluster center), and the following estimates: the distance inferred from UBV photometry and optical spectra for cluster members ($d = 429 \pm 8$ pc, Turner et al. 2012), the mean Hipparcos parallax for cluster stars (420 ± 33 pc, van Leeuwen 2007; Turner et al. 2012), the ISB distance for SU Cas ($d = 414 \pm 12$ pc, Storm et al. 2011; Turner et al. 2012), the original Hipparcos Cepheid parallax ($d = 433 \pm 116$ pc, Perryman & ESA 1997), and the revised Hipparcos Cepheid parallax ($d = 395 \pm 50$ pc, van Leeuwen 2007). A weighted mean of $d = 414 \pm 5(\sigma_{\bar{x}}) \pm 10(\sigma)$ pc was established after assigning $w = 3$ to the ISB, JHK_s , and UBV distances, $w = 2$ for the revised Hipparcos distance, and $w = 1$ for the original Hipparcos distance. $\sigma_{\bar{x}}$ is the standard error, σ is the standard deviation, and w is the weight. Lastly, the absolute Wesenheit magnitude ($W_{V_{Ic}}$) for SU Cas implied by that distance should be corrected for contamination from the companion (Evans 1991, 1992, see also Turner et al. 2012).

3. CONCLUSION & FUTURE RESEARCH

New XMM-Newton and OMM JHK_s photometry for Alessi 95, in conjunction with existing UCAC3 and 2MASS observations, imply cluster parameters of: $E(J - H) = 0.08 \pm 0.02$ and $d = 405 \pm 15$ pc (Figs. 1, 3). The determination confirms the findings by Turner et al. (2012), and in particular that SU Cas is an overtone pulsator (Gieren 1982; Evans 1991). Distance estimates for SU Cas (i.e., ISB, Hipparcos, cluster membership) converge upon $d = 414 \pm 5(\sigma_{\bar{x}}) \pm 10(\sigma)$ pc (§2.4). The small uncertainty places SU Cas in a select group of classical Cepheid calibrators (δ Cep and ζ Gem) that exhibit precise distances owing to cluster membership and the availability of trigonometric parallaxes. Yet the establishment of an HST parallax for SU Cas remains desirable in order to corroborate (or *refute*) the results. HST FGS images are available for SU Cas and were obtained as part of proposal ID 10113 (Bond 2004). Moreover, reducing the UCAC3 proper motion uncertainties and potentially extending the analysis to fainter stars would strengthen the distance derived. Precise proper motions for fainter stars near SU Cas may be obtained from photographic plates stored at the CfA (Grindlay 2007, DASCH).⁴ The plates offer unprecedented multi-epoch coverage spanning a ~ 100 year baseline, and uncertainties are further mitigated owing to sizable statistics ($\sim (5 - 10) \times 10^2$ plates per object).

⁴Digital Access to a Sky Century @ Harvard (DASCH), <http://hea-www.harvard.edu/DASCH/>

Lastly, XMM-Newton X-ray data proved pertinent for segregating cluster members from field stars, thereby highlighting a novel approach for establishing improved distances for cluster Cepheids (see also Evans 2011). Identifying members of Cepheid clusters using X-ray and proper motion data, as demonstrated here for SU Cas, may invariably bolster the Cepheid calibration (e.g., Ngeow 2012) and efforts to establish extragalactic distances (e.g., Shappee & Stanek 2011; Gerke et al. 2011; Freedman & Madore 2010). Admittedly, considerable work remains to fine-tune the former approach and maximize full use of the available X-ray data. Furthermore, additional work is needed to anchor the long-period end of the Galactic Cepheid calibration, despite continued advancements to secure the short and intermediate-period regimes. Future research shall aim to assess the viability of establishing long-period Cepheid calibrators from their membership in spiral arms, which are likewise delineated by young open clusters (see Majaess et al. 2011c).

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REFERENCES

Artigau, É., Lamontagne, R., Doyon, R., & Malo, L. 2010, *Proc. SPIE*, 7737
 Barnes, T. G. 2009, *American Institute of Physics Conference Series*, 1170, 3
 Benedict, G. F., McArthur, B. E., Fredrick, L. W., et al. 2002, *AJ*, 124, 1695
 Benedict, G. F. et al., 2007, *AJ*, 133, 1810
 Berdnikov, L. N., Dambis, A. K., & Vozyakova, O. V. 2000, *A&AS*, 143, 211
 Berdnikov, L. N. 2008, *VizieR Online Data Catalog*, 2285, 0
 Bonatto, C., Bica, E., & Girardi, L. 2004, *A&A*, 415, 571
 Bond, H. 2004, *HST Proposal*, 10113
 Cutri, R. M., et al. 2003, *The IRSA 2MASS All-Sky Point Source Catalog*, NASA/IPAC Infrared Science Archive.
 de Zeeuw, P. T., Hoogerwerf, R., de Bruijne, J. H. J., Brown, A. G. A., & Blaauw, A. 1999, *AJ*, 117, 354
 Evans, N. R. 1991, *ApJ*, 372, 597
 Evans, N. R. 1992, *ApJ*, 389, 657
 Evans, N. R. 1995, *ApJ*, 445, 393
 Evans, N. 2009, *HST Proposal*, 12215
 Evans, N. R., Guinan, E., Engle, S., et al. 2010, *AJ*, 139, 1968
 Evans, N. R. 2011, *IAU Symposium*, 272, 537
 Fouque, P., & Gieren, W. P. 1997, *A&A*, 320, 799
 Freedman, W. L., & Madore, B. F. 2010, *ARA&A*, 48, 673
 Gerke, J. R., Kochanek, C. S., Prieto, J. L., Stanek, K. Z., & Macri, L. M. 2011, *ApJ*, 743, 176
 Gieren, W. 1976, *A&A*, 47, 211
 Gieren, W. 1982, *PASP*, 94, 960
 Gieren, W., Storm, J., Barnes, T. G., III, et al. 2005, *ApJ*, 627, 224
 Grindlay, J. E. 2007, *The Central Engine of Active Galactic Nuclei*, 373, 711
 Jansen, F., Lumb, D., Altieri, B., et al. 2001, *A&A*, 365, L1
 Kovtyukh, V. V., Soubiran, C., Luck, R. E., et al. 2008, *MNRAS*, 389, 1336
 Laney, C. D., & Caldwell, J. A. R. 2007, *MNRAS*, 377, 147
 Macri, L. M., & Riess, A. G. 2009, *American Institute of Physics Conference Series*, 1170, 23
 Majaess, D. J., Turner, D. G., & Lane, D. J. 2008, *MNRAS*, 390, 1539
 Majaess, D. J., Turner, D. G., Lane, D. J., & Krajci, T. 2011 (a), *JAASO*, 39, 219
 Majaess, D., Turner, D., Moni Bidin, C., et al. 2011 (b), *ApJ*, 741, L27

Majaess, D., Turner, D., & Gieren, W. 2011 (c), *ApJ*, 741, L36
 Majaess, D., Turner, D., & Gieren, W. 2012 (a), *ApJ*, 747, 145
 Majaess, D., Turner, D., Gieren, W., Balam, D., & Lane, D. 2012 (b), *ApJ*, 748, L9
 McArthur, B. E., Benedict, G. F., Harrison, T. E., & van Altena, W. 2011, *AJ*, 141, 172
 Ngeow, C.-C. 2012, *ApJ*, 747, 50
 Paunzen, E. 2008, *Contributions of the Astronomical Observatory Skalnate Pleso*, 38, 435
 Perryman, M. A. C., & ESA 1997, *ESA Special Publication*, 1200
 Randich, S., Schmitt, J. H. M. M., Prosser, C. F., & Stauffer, J. R. 1996, *A&A*, 305, 785
 Riess, A. G., Macri, L., Casertano, S., et al. 2011, *ApJ*, 730, 119
 Shappee, B. J., & Stanek, K. Z. 2011, *ApJ*, 733, 124
 Soderblom, D. R., Nelan, E., Benedict, G. F., et al. 2005, *AJ*, 129, 1616
 Stetson, P. B. 1987, *PASP*, 99, 191
 Storm, J., Gieren, W., Fouqué, P., et al. 2011, *A&A*, 534, A94
 Straižys, V., & Lazauskaitė, R. 2009, *Baltic Astronomy*, 18, 19
 Turner, D. G. 2009, *American Institute of Physics Conference Series*, 1170, 59
 Turner, D. G. 2010, *Ap&SS*, 326, 219
 Turner, D. G. 2011, *RMxAA*, 47, 127
 Turner, D. G., Majaess, D. J., Lane, D. J., et al. 2012, *MNRAS*, 2750
 Usenko, I. A., Kovtyukh, V. V., Klochkova, V. G., Panchuk, V. E., & Yermakov, S. V. 2001, *A&A*, 367, 831
 van Leeuwen, F. 2007, *A&A*, 474, 653
 van Leeuwen, F. 2009, *A&A*, 497, 209
 Zacharias, N., Finch, C., Girard, T., et al. 2010, *AJ*, 139, 2184